Smalltalk Implementation:
Optimization Techniques

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Optimization Ideas

- Just-In-Time (JIT) compiling
  When a method is first invoked, compile it into native code.
- Caching the Method Dictionary
  Method Look-up will be speeded up.
- Inline Method Sending
  Will turn many SENDs into native CALL instructions
- Use the hardware calling stack
  MethodContexts → activation records allocated on a stack
- Code the VM directly in Smalltalk
  Automatic translation into "C"

Misc Points

Porting the Smalltalk Interpreter

The virtual machine is implemented in Smalltalk!

Using a subset of Smalltalk, called "*Slang*"

The image also includes a translator / compiler

Slang→ "C"

Steps to porting:

- **Produce automatically generated interpreter in "C"**
- **Hand-code the machine-dependent parts in "C"**
- **Compile**
- **Use any existing image**

Misc Points

Porting Images

Each VM executes the same bytecodes.
***Any* image can be executed on by *any* VM.**

EXAMPLE: An image produced on *MAC OS X* can be executed on *Windows*.

Porting Code Fragments

Misc Points

Porting Images

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can be executed on *Windows*.

Porting Code Fragments

Also, code fragments can be *filed out*
… and *filed in* to another image

Will it work?

The Smalltalk language is uniform.
What pre-existing classes does the code use?

Misc Points

Hash Values

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Dictionary, *Set*, etc.

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Need special VM support for hash values!

- Each object contains a hash value.
- 12 bits
- Stored in it header
- Initialized when the object is created

Optimizations to the Interpreter

Virtual Machine

Does not match underlying hardware well

Examples:

- OOP/SmallInteger Tagging
- Registers versus Stacks in Context objects

Bytecodes vs. Machine Instructions

The bytecodes are interpreted

- Fetch-decode-execute done at two levels.

Difficult to optimize bytecodes

- Bytecodes are complex operations
  - Corresponding to several machine level instructions

"Just in Time" Compiling

Translate bytecodes into native machine language

… and execute them directly

Do it "on the fly"

… on individual methods

Source → bytecodes → machine instructions

When the method is first invoked…

- Call the JIT compiler
- Translate bytecodes to native instructions
- Save the native code for next time.

"Just in Time" Compiling

Benefits:

- Optional
  Compatible with existing system
- Still have bytecodes
  (for the debugging tools)
- Can perform many optimizations at the native code level
- Can do it just to frequently invoked methods
- Running out of memory?
  Throw away some of the compiled methods

"Just in Time" Compiling

Problem:

Activation records are user-visible

MethodContexts, ***BlockContexts***

Activation record contains a pointer to the current bytecode

"instructionPointer" = "Program Counter (PC)"

Used by the debugging tools!

Solution:

"Just in Time" Compiling

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Solution:

Whenever an activation record becomes user-visible…

Map the native code PC back into a bytecode PC

Allocating Contexts on the Hardware Stack

The hardware supports stacks & procedure CALLs well.

"*stack frame*" = "*activation record*"

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Smalltalk VM…

linked list of ***Context*** objects

Want to use the hardware stack

Want to store each ***Context*** as a "stack frame"

Contexts are usually allocated in LIFO (stack) order.

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Asks for a pointer to the current context

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The Idea:

Store stack frames on hardware stack, not as objects.

When a pointer is generated to the current context…

Convert the stack frame into a real object.

Details

Converting a stack frame into a real object…

Allocate a new ***Context*** object and fill in its fields

Convert the program counter (PC)

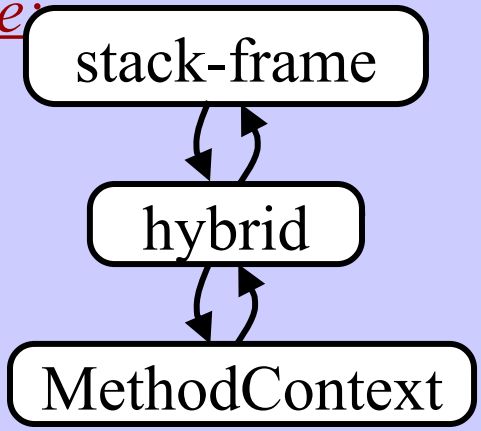
absolute address → byte offset into a ***CompiledMethod*** object

Contexts point to other ***Context***s

But other ***Context***s are still on hardware stack

Convert all frames into Objects…? No!

The Technique:



Caching the Method Dictionary

Method Lookup:

Given:
- the receiver's class
- the message selector

Find:
- the right ***CompiledMethod***

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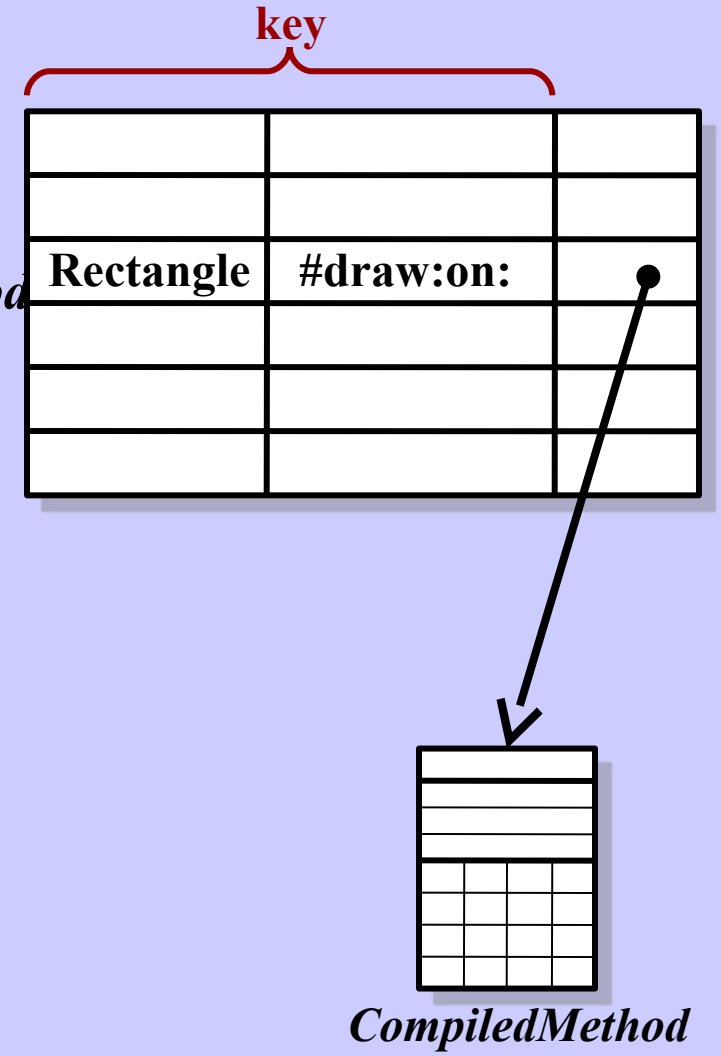

The Idea:

Use a Hash Table

Maintained by the VM

(it is not an object)

Not in the hash table?
- Do a full method lookup
- Add an entry to the hash table

Inline Method Caching

Assume methods are compiled into native code.

Code to send a message:

```
< code to push receiver >
< code to push args >
CALL MessageSend (arg = selector)
```

A machine-language CALL instruction

A routine that searches for the proper method/routine and then calls it.

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Assume methods are compiled into native code.

Code to send a message:

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< code to push receiver >
< code to push args >
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```

The Idea:

- Upon locating the correct routine…
  Replace the CALL to the "MessageSend" routine
  … with a CALL straight to the native code routine!
- Next time we execute the above code,
  we CALL the right routine immediately.
- Gradually all message sends are replaced with
  native code CALL instructions.

Inline Method Caching

Problem:

Dynamic Look-Up

The receiver's class determines which method to invoke.
Different class? → Different method!

Assumption:

Approach:

Inline Method Caching

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Assumption:

Any particular SEND will invoke the same method
... almost always!

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Dynamic Look-Up

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Approach:

At the beginning of each method:

- Check the class of the receiver
- If it is what this method expects

… continue with this method.

- If the receiver has the wrong class…
- Perform a full method lookup.
- Overwrite the CALL (to jump to the correct method next time)
- Jump to the correct method.

Effectiveness of Optimizations

	space	time
Straight interpreter	1.0	1.0
Compiler	2.3	.69
Compiler w/ inline caching	3.4	.62
Compiler w/ peephole optimizer	5.0	.56
Compiler w/ inline caching w/ optimizer	5.0	.51